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Modeling of complex processes in turbulent flow of unstable emulsions of immiscible liquids

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Abstract

© 2017, Budapest University of Technology and Economics. All rights reserved. Turbulent flows of emulsions are associated with the processes of breakage, coalescence and sedimentation of droplets of dispersed liquid. Mechanisms of these physical phenomena that form the equilibrium composition of the droplets of dispersed phase are predetermined by the structure of turbulence. Spectrum of distribution of the dispersed droplets according to the size determines in turn the nature of the interaction with the continuous medium. Therefore, a hydrodynamic model for unstable emulsion (CFD) is completed by discrete population balance model (DPB). It reflects the state of the dispersed phase of the emulsion required to construct an adequate model for CFD. A joint application requires the coordination of the composition and structure of these models for formalizing of the complex interrelationships of physical phenomena in the continuous medium and the dispersed phase of the emulsion. The key advantages of such specification of the overall structure of the partial models of the CFD consist in that model includes only the mechanisms of breakup, coalescence and sedimentation of the droplets of the dispersed phase, which are really work in the given conditions. Using of a priori theoretical information in the form of mechanisms of basic physical phenomena (MBPP) is proposed, which is necessary for obtaining the desired particular solutions of applied problems on the basis of common CFD and DPB models.

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Keywords

Basic physical phenomena, CFD flow simulation, Liquid-Liquid emulsions, Model structure, Population balance model, Turbulent flow

References

[1] Xing, C., Wang, T., Wang, J. "Experimental study and numerical simulation with a coupled CFD–PBM model of the effect of liquid viscosity in a bubble column." Chemical Engineering Science. 95, pp. 313–322. 2013. https://doi.org/10.1016/j.ces.2013.03.022

[2] Gao, Z., Li, D., Buffo, A., Podgórska, W., Marchisio, D. L. "Simulation of droplet breakage in turbulent liquid–liquid dispersions with CFD-PBM: Comparison of breakage kernels." Chemical Engineering Science. 142, pp. 277–278. 2016. https://doi.org/10.1016/j.ces.2015.11.040

[3] Ramkrishna, D. "Population balances. Theory and applications to particulate systems in engineering." Academic Press, New York, NY. 2000.

[4] Ramkrishna, D., Mahoney, A. W. "Population balance modeling. Promise for the future." Chemical Engineering Science. 57(4), pp. 595–606. 2002. https://doi.org/10.1016/S0009-2509(01)00386-4

[5] Rozentsvaig, A. K., Strashinskii, Ch. "Mechanisms of boiling of an emulsion with a low-boiling disperse phase in a turbulent flow of a homogeneous emulsion." Journal of Engineering Physics and Thermophysics. 83(3), pp. 486–495. 2010. https://doi.org/10.1007/s10891-010-0369-4

[6] Yeoh, G. H., Tu, J. Y. "Two-fluid and population balance models for subcooled boiling flow." Applied Mathematical Modelling. 30, pp. 1370– 1391. 2006. https://doi.org/10.1016/j.apm.2006.03.010

[7] Abidin, M., Raman, A., Nor, M. "Mean drop size correlations and population balance models for liquid—liquid dispersion." AIChE Journal. 61(4), pp. 1129–1145. https://doi.org/10.1002/aic.14751

[8] Rozentsvaig, A. K., Pergushev, L.P. "Coalescence of concentrated fine-disperse emulsions during turbulent stirring." Journal of Engineering Physics. 40(6), pp. 608-612. 1981. https://doi.org/10.1007/BF00825447

[9] Rozentsvaig, A. K. "Breakup of droplets in turbulent shear flow of dilute liquid-liquid dispersions." Journal of Applied Mechanics and Technical Physics. 22(6), pp. 797–802. 1981. https://doi.org/10.1007/BF00906109

[10] Rosentsvaig, A. K. "Coalescence of coarsely dispersed concentrated emulsions with turbulent agitation." Journal of Engineering Physics. 42(1), pp. 19–24. 1982. https://doi.org/10.1007/BF00824984

[11] Rozentsvaig, A. K. "Turbulent pipe flow of concentrated emulsions with a non-equilibrium disperse phase." Journal of Engineering Physics. 42(3), pp. 254–259. 1982. https://doi.org/10.1007/BF00827741

[12] Rozentsvaig, A. K., Strashinskii, C. S. "Identification of models of transfer processes in complex disperse systems." Applied Mathematical Sciences. 10(24), pp. 1151–1161. 2016. https://doi.org/10.12988/ams.2016.6137

[13] Rozentsvaig, A. K. "Numerical analysis of equilibrium droplet spectrum formation in turbulent transverse flow of polydispersed concentrated emulsions." Journal of Applied Chemistry of the USSR. 61, pp. 2450–2455. 1988.

[14] Zhang, Y., Jia, M., Liu, H., Xie, M. "Development of an improved liquid film model or spray/wall interaction under engine-relevant conditions." International Journal of Multiphase Flow. 79, pp. 74–87. 2016. https://doi.org/10.1016/j.ijmultiphaseflow.2015.10.002

[15] Kolmogorov, A. N. "On the breakage of drops in a turbulent flow." Doklady Akademii Nauk SSSR. 66. pp. 825–828. 1949.

[16] Taylor, G. I. "The formation of emulsions in definable fields of flow." Proceedings of the Royal Society A: Mathematical, Physical & Engineering Sciences. 146, pp. 501–523. 1934. https://doi.org/10.1098/rspa.1934.0169

[17] Slecher, C. Jr. "Maximum stable drop size in turbulent flow." AIChE Journal. 8, pp. 471–477. 1962. https://doi.org/10.1002/aic.690080410

[18] Sarimeseli, A., Kelbaliyev, G. "Deposition of dispersed particles in isotropic turbulent flow." Journal of Dispersion Science and Technology. 29(2), pp. 307–312. 2008. https://doi.org/10.1080/01932690701688839

[19] Ryazhskikh, A. V., Boger, A. A., Slyusarev, M. I., Ryazhskikha, V. I. "Convective-diffusion model of transfer of a sedimenting low-concentration polydisperse suspension of stokesian particles in a plane channel. Part 1." Journal of Engineering Physics and Thermophysics. 89(1), pp. 10-18. 2016. https://doi.org/10.1007/s10891-01--1348-1

[20] Rozentsvaig, A. K. "Structure analysis of mechanism of weighing of particles in a turbulent flow of liquid disperse systems." Izvestiâ Vyših Učebnyh Zavedenij. Problemy Energetiki. No. 9-10, pp. 19-34. 2003. (in Russian)

[21] Balachandar, S., Eaton, J. "Turbulent dispersed multiphase flow." Annual Review of Fluid Mechanics. 42(1), pp. 111–133. 2010. https://doi.org/10.1146/annurev.fluid.010908.165243

[22] Montoya, G., Lucas, D., Baglietto, E., Liao, Y. "A review on mechanisms and models for the churn - turbulent flow regime." Chemical Engineering Science. 141(2), pp. 86–103. 2016. https://doi.org/10.1016/j.ces.2015.09.011

[23] Andreini, A., Bianchini, C., Puggelli, S., Demoulin, F. X. "Development of a turbulent liquid flux model for Eulerian–Eulerian multiphase flow simulations." International Journal of Multiphase Flow. 81, pp. 88–103. 2016. https://doi.org/10.1016/j.ijmultiphaseflow.2016.02.003

[24] Joshi, J., Nere, N., Rane, C., Murthy B., Mathpati C., Patwardhan, A., Ranade, V. "CFD simulation of stirred tanks: Comparison of turbulence models. Part I: Radial flow impellers." The Canadian Journal of Chemical Engineering. 89(1), pp. 23-82. 2011. https://doi.org/10.1002/cjce.20446

[25] Hakansson, A., Fuchs, L., Innings, F., Revstedt, J., Tragardha, Ch., Bergenstahl, B. "Experimental validation of k–ε RANS-CFD on a high-pressure homogenizer valve." Chemical Engineering Science. 71, pp. 264–273. 2012. https://doi.org/10.1016/j.ces.2011.12.039

[26] Rozentsvaig, A. K. "Mechanism of the comminution of drops during the mixing of dilute emulsions with turbine-driven agitators." Journal of Applied Chemistry of the USSR. 58, pp. 1191-1198. 1985. https://doi.org/10.13140/RG.2.1.4152.1527

[27] Zeigarnik, Yu., Platonov, D, Khodakov, K., Shekhter, Yu. "Visualization of boiling of subcooled water." High Temperature. 49(4), pp. 566–570. 2011. https://doi.org/10.1134/S0018151X11020179

[28] Galbraith, S. C., Schneider, P. A., Flood, A. E. "Model-driven experimental evaluation of struvite nucleation, growth and aggregation kinetics." Water Research. 56(6), pp. 122–132. 2014. https://doi.org/10.1016/j.watres.2014.03.002

[29] Rozentsvaig, A. K., Strashinskii, C. S. "Modeling of heat transfer conditions in cooling lubricant emulsions with low-boiling continuous media in narrow gaps." International Journal of Heat and Mass Transfer. 102, pp. 550–560. 2016. https://doi.org/10.1016/j.ijheatmasstransfer.2016.06.072